

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/266184768>

# A short history of mineral processing

Article · January 2006

---

CITATIONS

6

---

READS

10,431

1 author:



**Fathi Habashi**  
Université Laval

639 PUBLICATIONS 4,334 CITATIONS

SEE PROFILE

**Pages 3 - 8**



*Proceedings of*  
**XXIII INTERNATIONAL  
MINERAL PROCESSING  
CONGRESS**

**Edited by**

G. ÖNAL, N. ACARKAN, M. S. ÇELİK, F. ARSLAN, G. ATEŞOK,  
A. GÜNEY, A. A. SİRKEÇİ, A. E. YÜCE, K. T. PEREK

**VOLUME 1**



ISTANBUL, TURKEY 3-8 SEPTEMBER 2006

# A short history of mineral processing

Fathi Habashi

Laval University, Quebec City, Canada

**ABSTRACT:** Crushing and grinding of ores and their beneficiation by washing away gangue minerals has been practiced since ancient times. Primitive crushing was done by hand pounding the ore with a hard stone then by using metallic hammers. The mortar and pestle was mechanized using a lever and when the size of operations increased in the middle ages, the stamp mill was introduced. The grindstone played an important role in grinding of ores. Panning for gold and hand sorting of minerals were two old methods of separation, now gave way to modern techniques. Flotation started in the middle of the nineteenth century by using oils to collect the mineral particles and float them on the surface of the aqueous slurry. It was only in the 1920s when it was discovered that organic compounds were affective floating agents. Textbooks written by distinguished engineers such as Rittinger, Rickard, Pryor, Taggart, Richards, Gaudin, and others contributed to the recognition of this field as a new discipline to be taught in Universities.

## 1 INTRODUCTION

The ancient Egyptians knew already that it would be easier to melt an earth rich in gold particles than another which is poor. As a result all efforts were made to enrich the gold by washing away the light gangue minerals (Figure 1). Another ancient method for enriching gold particles from a river stream was by means of fleece, hence the Greek myth of the “golden fleece”. The present day Georgia was known in ancient times as Colchis and was a center for gold working. It was known to the ancient Greek as the land of Golden Fleece.

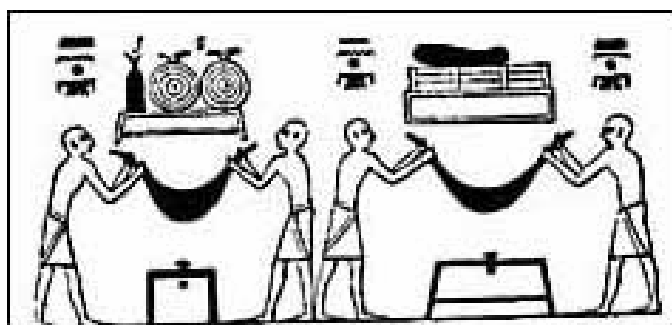


Figure 1. Beneficiation of gold by washing. An ancient Egyptian wall painting

In the middle Ages, when trees in Europe were cut on a large scale to supply wood as a fuel for the smelting furnaces it was realized that, to economize the consumption of wood it would be necessary to

remove as much as possible of the gangue minerals from the charge to the furnace. Hence more effort was directed to beneficiate the ores. The most important ores treated at that time were those of copper, iron and silver. In fact most of the silver was recovered from lead ores. To enrich an ore in its valuable minerals it was necessary to crush it into small fragments then pick up the mineral values and discard the valueless minerals. Hence crushing of ores became the first step in beneficiation.

In the early years of the schools of mines, teaching of mining and metallurgy, and sometimes geology and mineralogy were taught by the same professor. Also, the tendency was to teach courses related to the exploitation of mineral resources. It was Peter von Rittinger (Figure 2) at the Schemnitz School of Mines in the Austrian Empire who first taught the subject of mineral dressing and wrote specialized books on this topic. It took some time when orientation of the College or Institute took shape in North America. Robert H. Richards (Figure 3) in USA was the first to organized a mineral dressing laboratory at Massachusetts Institute of Technology in Boston and published a series of books on the subject that started in 1903. However, the first chair in mineral dressing was founded in 1919 at Columbia School of Mines and was occupied by Arthur F. Taggart (1884-1959) who authored *Handbook of Ore Dressing* in 1927. Mineral dressing was continued to develop at MIT



when Antoine M. Gaudin (1900-1974) joined in 1939, who also taught mineral dressing at Columbia, Utah, and Montana before joining the MIT.



Figure 2. Peter von Rittinger (1811-1872)

Most of the topics of mineral beneficiation, however, were divided between chemical engineering and metallurgy books until recently that the subject became well defined and an independent domain. The International Mineral Processing Congress was organized in the 1950s and the first congress took place in London in 1952, thanks to the efforts of P. Gy, Jacques E. Astier, C.W. Dannatt, and others.

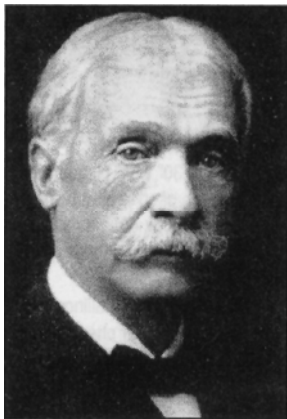


Figure 3. Robert H. Richards (1844-1945)

## 2 COMMINATION

To the modern mineral processing engineer crushing of ores takes place in large jaw or gyratory crushers that can handle thousands of tons per hour. Similarly grinding is conducted in huge rotary equipment charged with steel rods or cast iron balls and can render tons of peanut-sized ore particles into powder like flour in a matter of minutes. These equipments are operated by pressing a button to allow the electric motors to start the machines in doing their function. The process is conducted continuously – the large lumps of ore are fed from one side and the fine product comes out from the others. A number of

these machines can be attended by may be one worker who will only be watching a television screen in his control room to make sure that each equipment is working. How did the ancient people crush and grind ores when there were no electric motors and no robust equipment conceived or built to do such work ?

### 2.1 Crushing

Rocks are crushed mainly by impact. The most primitive form was holding a hard stone in the hand and pounding the rock containing the valuable minerals (Figure 4). Archeologists have found many such stones. In Agricola's time, the ore was pounded with bats until the desired size of particles were obtained (Figure 5). Metallic hammers were also used by primitive people. The mortar and pestle is still used in everyday life.



Figure 4. Crushing by hand-pounding with a hand stone

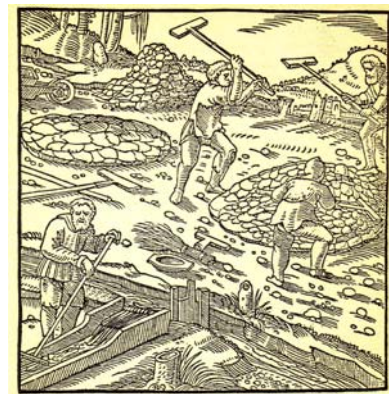


Figure 5. Crushing by pounding with bats in Agricola's time

The application of the principle of levers helped save some of the human effort. An ancient Chinese drawing shows the use of a lever to facilitate the operation of the mortar and pestle (Figure 6). A recent painting made in South Africa depicts a group of workers crushing ore particles using a granite boulder that is being balanced once to left and once to the right by two workers sitting on a tree trunk mounted on the top of the boulder (Figure 7). When the size of operations increased in the middle ages, the stamp mill was introduced in which numerous pestles were powered by a water wheel (Figure 8) or by horses.

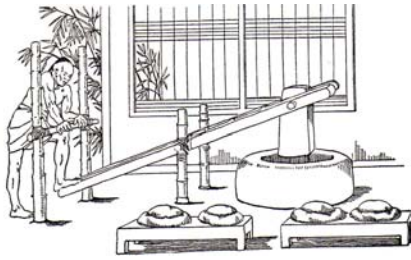


Figure 6. Using the principle of lever to crush ores



Figure 7. Crushing an ore by bouncing a granite boulder

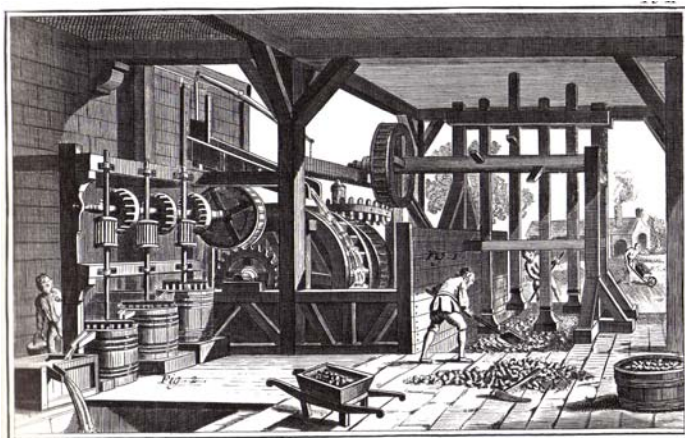


Figure 8. A stamp mill operated by a water wheel

The stamp mill is closely related to the recovery of gold by amalgamation, a process now obsolete. The crushed ore leaving the mill was allowed to flow over an inclined copper plate covered with a thin layer of mercury. Large gold particles were immediately captured by mercury forming amalgam. From time to time the plate was wiped clean by a cloth, the amalgam recovered was saved for future distillation, and a fresh layer of mercury then introduced. Naturally the health hazard associated with handling of mercury and the amalgam resulted in abandoning this technology.

When the steam engine was invented it replaced both the horses and the water wheel. The modern crushing equipment was invented in the second half of the nineteenth century. The jaw crusher by Joshua H. Blake in 1858, the gyratory crusher by Gates in 1883.

## 2.2 Grinding

In many cases the crushed ore particles are not sufficiently small to permit liberation of the desired mineral so that separation can be achieved. Decreasing the particle size is usually conducted by applying a shearing force. A recent photograph taken in South America shows a boy grinding some material by balancing a small millstone by his hands (Figure 9). The technique was improved by allowing the mineral particles to flow between two horizontally laid grindstones, one on top of the other. The lower millstone has grooves on the side touching the upper millstone. The upper millstones can be rotated manually by a handle while the lower one is stationary. A hole is provided in the upper millstone to allow introducing the ore. The grinding action takes place between the two surfaces. The ground material falls from all sides and can be collected (Figure 10).



Figure 9. A boy grinding ore with a grindstone



Figure 10. Grinding a material manually between two grindstones - the buhrstone mill

The movement of the millstones was also mechanized by the circular movement of an animal as shown in Figure 11. The millstone is a high strength quartz sandstone containing a small amount of clay or limestone as a binder. It is usually cut into discs about 2m diameter and 30cm thick; it weighs about 2 tonnes. A central hole is perforated through which a long log is mounted, and is then driven by animal power. Figure 12 shows the partition of the



pieces in the quarry and the workers preparing the millstone, cutting it, sliding it out of the mine, and finally transporting it on a horse-driven chariot (Figure 13).

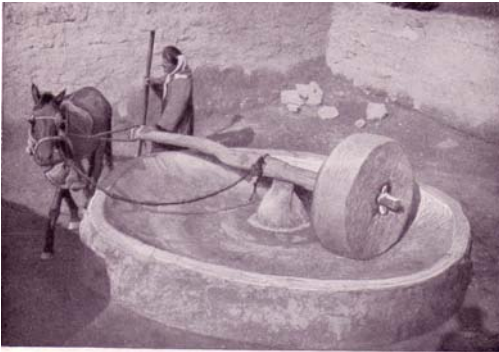


Figure 11. An animal is used to operate a grinding unit

The equipment was re-designed by modern engineers and was described in chemical engineering textbooks in 1940s (Figures 14-16). The modern grinding equipment, i.e., the ball mill was



Figure 13. Transportation of the grindstone (1806) invented in Germany by Brückner in 1876.



Figure 12. Quarrying of grindstone, 1806

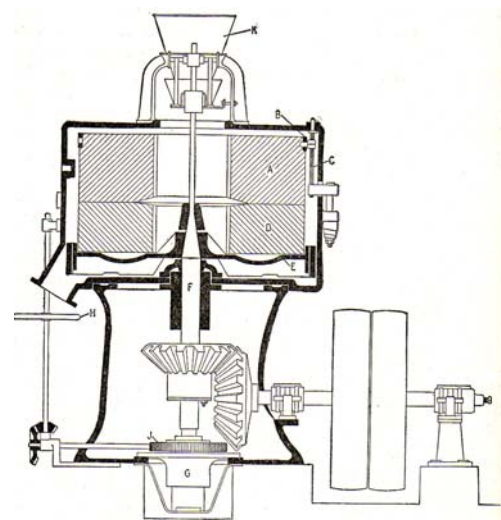


Figure 14. Mechanized buhrstone

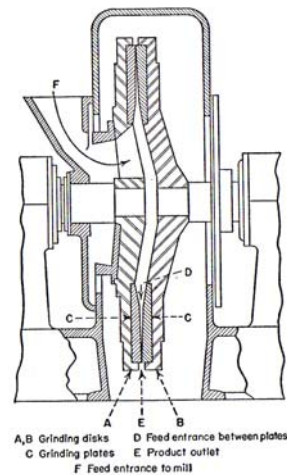


Figure 15. Another version of a mechanized buhrstone

### 3 SEPARATION OF MINERALS

Panning of gold is probably the oldest way of separating mineral particles by gravity (Figure 17). The attraction of iron particles to a certain kind of a naturally-occurring rock near the village of

Magnesia near Izmir in Asia Minor was also known since ancient times. However, it was William Gilbert (1544-1603) the physician to Queen Elizabeth I, who described this phenomenon as magnetism and the naturally-occurring rock possessing this phenomenon, as magnetite. With the discovery of electromagnetic induction in the nineteenth century, it became possible to have strong magnets capable of separating magnetic from non-magnetic minerals.

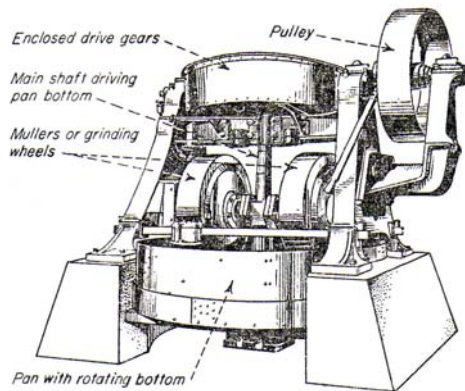


Figure 16. A variant design of a buhrstone mill



Figure 17. Panning for gold

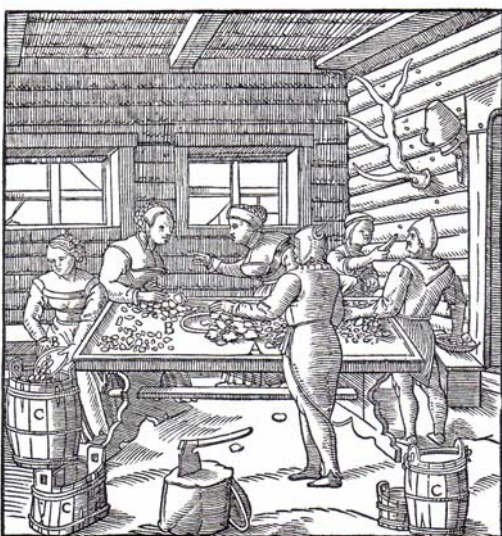


Figure 18. Hand sorting (1556)

Hand sorting was a common method to pick up the valuable pieces of ore from the gangue (Figure

18). This method was used till the mid twentieth century (Figure 19) when it was replaced by a variety of other methods based on electrostatic properties, radioactivity, X-ray fluorescence, etc. Arthur Redman Wilfley (1860-1927) in Arizona invented in 1896 a shaking table for separating minerals while Humphrey spiral came into use in about 1940s.



Figure 19. Hand sorting (1910)

Flotation is now the most important mineral beneficiation method. Froth flotation as practiced at present was preceded by many attempts to float minerals using certain oils such as pine oil: certain mineral particles clinged to the oil layer which is lighter than water, hence it was floated. For example, the process used by William Haynes in England in 1860. At the beginning of the twentieth century it was recognized by Elmore in 1904 and Sulman *et al.* in 1906, that the use of large amounts of oil was unnecessary and even objectionable and that the replacement of some oil by air as the buoyant medium was more advantageous.

In 1909, Greenway, Sulman, and Higgins advanced the art through their discovery of soluble frothing agents such as ketones and alcohols, which permitted still further reduction of the quantity of oils formerly required for flotation. From 1913 to 1922, flotation may be said to have first attained commercial success, particularly in the United States. The first commercial plant of importance being that of the Butte & Superior Company placed in operation in 1913. A wide variety of oils, such as wood and coal-tar creosotes, were used as collectors in conjunction with frothers, such as pine oils and rosin oils, for the sulfide minerals. It is to be noted that all these collectors were of indefinite chemical composition. Bulk sulfide concentrates were recovered in as much as it was not possible to separate on sulfide mineral from another with the known flotation reagents of that era.



The modern era in this technology may be marked by Perkin's discovery in 1921 of the effectiveness of definite chemical compounds such as alpha-naphthylamine and thiocarbanilide in promoting the flotation of sulfide minerals. This was followed by the discovery of Keller and Lewis in 1924 that water-soluble xanthates are effective flotation agents. Since then other discoveries followed such as the use of cyanide as depressant for pyrite and sphalerite in alkaline solution, etc.

The theory of flotation was first advanced by Irving Langmuir (Figure 20) in 1920 as an absorption phenomenon on the surface of the mineral and the adhesion of the mineral to the bubbles of air forming a froth. The theory was elaborated further by L.J. Christmann of the American Cyanamid Company in USA in 1930. Application of flotation to non-sulfides has been increasing. Satisfactory results have been obtained in the treatment of mineral phosphates, of cement rock, of crude salines (such as potassium ores), and also of impure fluorite and barite. Another field of application of flotation is to the making of high-grade iron concentrates from low-grade primary ores and the cleaning of coal.



Figure 20. Irving Langmuir (1881-1957)

Flotation was always conducted in agitated tanks. The suggestion to use columns in flotation was proposed by P. Poutin and R.J. Tremblay in a US patent issued in 1967. It was in 1980 when columns were installed for the first time at Mine Gaspé in Quebec, Canada. It was found out that two columns: one 45.7 cm and another 91.4 cm replaced 13 stages of cells in a molybdenite circuit. Few years later, the copper industry in Chile adopted column flotation cells in some of its operations and since then their use became wide spread. The major advantage of the columns is the absence of moving parts hence they are nearly maintenance free. In 1988 the first

international conference on column flotation was held in Phoenix, Arizona by the Society of Mining Engineers of AIME, to mark this innovation.

## 4 EPILOGUE

Mineral processing was an art till the 1920s when it started to become a science. About three decades later it became a highly sophisticated science - - thanks to the new generation of young engineering graduates.

## 5 SUGGESTED READINGS

### 5.1 General

- Bond, F.C., *The third theory of comminution*, Trans. AIME, Min. Engineering 193, 484-494 (1952)
- Gaudin, A.M. *Principles of mineral dressing*, McGraw Hill, New York 1939
- Habashi, F., *The quarring of grindstone by Johann Eingelegner. A manuscript written in 1806, translated and published in 1990*, CIM Bulletin 84 (1959), 96-97 (1992)
- Habashi, F., *Readings in historical metallurgy – volume 1: Changing technology in extractive metallurgy*, Chapters 10 and 11, Métallurgie Extractive Québec 2006, distributed by Laval University Bookstore
- Kick, F., *Das Gesetz des Proportionalen Widerstand und seiner Anwendung*, Arthur Félix, Leipzig 1885
- Liddell, D.M., editor, *Handbook of nonferrous metallurgy*, volume 1, Principles and processes, McGraw Hill, New York 1926, Second Edition 1945
- Richards, R.H., *Ore dressing*, 1909
- von Ritinger, P., *Lehrbuch des Aufbereitungskunde*, Berlin 1867
- Taggart, A.F., *Handbook of ore dressing*, Wiley, New York, 1927

### 5.2 Flotation

- Christmann, L.J., *Chemistry and the flotation process*, Tech. Paper 17, American Cyanamid Company, 1930
- Fahrenwald, A.W., *Surface Reactions in Flotation*, Trans. AIME, Vol. 70, 1924
- Gaudin, A.M., *Mineral concentration by adhesion in the XV<sup>th</sup> century*, Eng. Mining J. 141 (10), 43-44 (1940)
- Langmuir, I., *The mechanism of the surface phenomena of flotation*, Trans. Faraday Soc., Vol. 15, 1920
- Richard, T.A., *Concentration by flotation*, Wiley, New York 1921
- Sastry, K.V.S., editor, *Column flotation '88*, Society for Mining Engineers, Littleton, Colorado 1988
- Sulman, H.L., *Flotation*, Trans. Inst. Min. & Met. (London) 29, 44-204 (1919)
- Wark, I.W., *Principles of flotation*, the Australasian Institute of Mining & Metallurgy, Melbourne 1938
- Wood, H. E., *Early efforts in flotation of dry minerals*, Eng. Mining J., 126, 571-573 (1928)